that if a sufficient quanitity of such recovered serum is given to patients in the pre-paralytic stage paralysis may be prevented. The serum should be given in the following way: 10 to 15 cc. intraspinally after removal of sufficient amount of spinal fluid and 50 to 100 cc. intravenously immediately afterward. These intravenous doses should be repeated within six to eight hours. The suggestion is made that it should be just as easy to secure donors for this anti-polio serum just as quickly as one secures donors for blood transfusions.

This paper does not pretend to discuss in extenso the whole matter of serum therapy, except to say that it is difficult to understand why the Rosenow serum which has been proved non-specific for the virus of poliomyelitis should be of any value.

(c) THE ORTHOPEDIC TREATMENT OF INFANTILE PARALYSIS

Fred H. Albee

The care of infantile paralysis, because of the diversity of the problems presented, tests the mechanical ingenuity of the surgeon, not only in devising proper braces which vary within very wide limits, but also in devising and selecting proper operative treatment, which affords a wide range of possibilities—from the simplest operation, such as a subcutaneous tenotomy, to the most difficult bone transplantation. Probably no other one disease requires so many different types of operations for its satisfactory treatment. Briefly they may be enumerated as follows: tendon and muscle lengthening, tendon and muscle transplantations, insertion of fascial or silk or linen ligaments, nerve transplantations, neurotization of muscles, osteotomies to overcome contractures and distortions, plastic operations on joints to improve function, stabilizing operations, such as reefing the joint capsule or overlying soft parts, or arthrodesing of the joint itself, not to mention bone transplantation to correct deformities of the joints or spinal column, and the insertion of bone grafts to stabilize joints, or prevent the telescoping of ribs into the pelvis by placing a graft between the tenth rib and the rim of the pelvis. It is not my purpose to list or to discuss all the many possibilities, for the orthopedic surgeon must ever be prepared to meet quickly and adequately unique individual problems, and to design at the moment suitable braces and operations.

There are three types of infantile paralysis: 1, the *abortive,* comprising those cases which have never become paralyzed; 2, the *cerebral,* those in which there is involvement of the upper motor neurone with resulting spastic paralysis; 3, the *bulbo-spinal*—by all means the largest group—in which are placed all cases in which the lower motor neurons are affected, with resultant flaccid paralyses. (Peabody, Draper, and Dochez's classification.)

The only objection to this classification is that the groups overlap. Cases are not always true to type, nor are the types always clearly defined. A case classified as bulbospinal may have brain foci; the cerebral case may have lesions extending into the cord.

The bulbospinal type is the one with which the orthopedic surgeon is chiefly concerned. This group is characterized by flaccid motor paralysis of the muscles supplied by the spinal nerves. The lumbar enlargement of the cord is the part chiefly affected, and hence paralysis of the lower limbs is more frequent than that of the upper. Involvement of the cervical swelling of the cord occurs less often, and consequently paralysis of the upper extremities is less frequent. The degree of the paralysis cannot be estimated by the severity of its onset.

Jahss has drawn some interesting conclusions regarding the distribution of paralysis from a clinical study of 400 cases of infantile paralysis during the great epidemic of 1916 in New York City—cases observed at the clinic of the Hospital for Joint Diseases. He found that in 78 per cent. of these cases there was some involvement of the lower extremities. Thirty-eight per cent. of the patients were paralyzed in one limb only, and of these, 10 per cent. in the upper extremity, and 28 per cent. in the lower. Twenty per cent. of the cases exhibited some form of paralysis of the trunk. The cranial nerves were affected in 13 per cent. of the cases, the seventh (facial) in the majority of the cases.

From the point of view of treatment, the disease may be considered as having *three stages:* the acute, convalescent, and chronic. The acute stage lasts from the onset of symptoms to the disappearance of muscular tenderness and the cessation of abnormal temperature. The convalescent stage—a purely arbitrary consideration—extends from the end of the acute stage to such time as spontaneous improvement has apparently ceased. This period usually lasts about two years, after which the condition becomes chronic.

In general, the treatment of infantile paralysis may be outlined as follows:

During the acute stage, efforts should be directed to limiting the destructive physiological process by administration of serum, by symptomatic treatment, and by prevention of faulty posture, so far as possible. This stage is rarely seen by the surgeon, but he too often sees the unfortunate results of well-intended but meddlesome treatment, which over-anxious parents often press the general practitioner to undertake during this phase; as for example, massage and electricity which, though of undoubted value later, at this stage only serve further to stimulate an already over-stimulated nervous system. It should be constantly borne in mind that one is dealing with nerve lesions, and that a quiet environment, rest, and the avoidance of all nerve stumli, such as excessive noise or light, are essential.

Joints will not become ankylosed, muscles will not hopelessly atrophy, and the patient will not become bed-ridden because he is kept quiet for a long a time as need be, to enable the damaged cord to repair without interference. This policy of doing nothing is trying to the parents who have heard of the wonders of massage and electricity, and are anxious that no time should be lost; and trying also even to the experienced surgeon when the tenderness is of unduly long duration.

The unsupported paralyzed foot in the acute stage, even if it does not become deformed, will surely lose power in the stretched muscles.

Certain deformities, most likely to occur, may be guarded against: 1—contracting the feet in plantar flexion, 2—flexion deformity of the knees, 3—flexion deformity of the hips, 4—adduction contraction of the shoulder, 5—lateral curvature of the spine.

The weight of the bed clothes, if not counteracted, often increases deformity; if the feet are in the equinus position because of the paralysis of the anterior group, the weight of the bed clothes further exaggerates the equinus. Various means have been devised to relieve this weight. Lovett further suggested special arrangement of the bed, or the use of a special bed, to control the patient's restless movements, and support those muscles most likely to be paralyzed or overstretched, thus preventing undue deformity during this active stage.

During the convalescent stage, or period of spontaneous improvement, no operative procedure aiming at correction of muscle balance should be undertaken. The aim and object of treatment during this stage is to restore the greatest possible amount of efficiency to the inactive, atrophied muscles, and to prevent permanent deformity. A mental picture of the general pathologic process must be kept constantly in mind, in order that treatment may be intelligently managed. It must be remembered that the nerve centers controlling these muscles have, in a certain percentage of cases, been only temporarily inhibited in function by a hemorrhagic myelitis, with a consequent impairment of circulation and lowering of the general resistance.

The upright position of the patient should be assumed early unless involvement of spinal muscles prohibits, for recumbency favors sluggish circulation, whereas sitting and standing stimulate the muscles and nerve centers to restore "balance"; furthermore, recumbency and inaction have an untoward effect on the nervous system. A sitting posture, and as soon as is advisable, restricted walking, should be practised within two or three months after onset, with, however, great care to avoid fatigue. Outdoor air is, of course, best for the patient on general principles.

The supportive braceage or splintage treatment is always applied during the convalescent period to those cases in which it is necessary to support limbs or trunk, which would otherwise become distorted. As much care should be taken to avoid under-bracing as should be exercised against over-bracing.

If the abdominal and spinal muscles are too weak to support the torso, the patient should be propped in the chair with pillows. It is important to be on the lookout for scoliosis at this time, and the patient must be put in a position to counteract its development.

Abdominal paralysis is common, but may be overlooked. The physical signs are inability of the patient to rise from recumbency to a sitting position without assistance and when upright, protrusion of the abdomen with anterior or lateral flexion of the spine. The result, if uncorrected, is eversion of the costal borders from pressure against the protuberant abdomen, and this deformity may become structural. Unilateral abdominal paralysis is less common. The abdomen should be supported in such cases by a strong corset of heavy duck or other material with inserted supporting steel which may also favor recovery of function by the abdominal muscles.

Braces

Even if the patient is able to walk unassisted, the weakened atrophied muscles are easily fatigued and are thereby injured; hence, the minimum amount of strain should be put upon them. If the patient cannot stand or walk without aid, or does so with the production of some deformity, *e.g.*, genu recurvatum, recourse must be had to braces, because it is imperative to get the muscles into use, at the same time supporting the limb and preventing the development of deformity. However, some patients, although extensively paralyzed in the legs, can manage to get about without assistance, and in such cases, unless some specific contra-indication exists, braces should be omitted.

Braces should be made as simple and light as possible, their sole purpose being to support the limbs and prevent recurrence of the deformity. This is of the greatest importance because in the growing period of a child's life its ligaments and capsules are easily over-stretched, thus permitting irreparable damage to the joints. The brace has to be devised to meet the requirements of the individual case at hand. There is no stereotyped brace that is applicable to all cases. In these days of so many infantile paralysis cases, we feel that it devolves upon us to emphasize the rule that the architecture of the brace should be draughted by the orthopedic surgeon for each individual. The brace should be light and as simple as possible, designed to afford the support lacking because of the paralyzed muscles, and should not interfere with the action of muscles capable of functioning.

For certain types of paralysis, *e.g.*, equinus, it should be made a general rule never to trust the shoe to support the foot. Leather can never be depended upon to withstand constant strain, for wetting causes it to yield, and therefore a foot plate of metal should be fastened to the brace.

The caliper splint, so frequently worn, wears out easily and causes much trouble, and its use is not favored by the author.

The *quadriceps extensor femoris* is one of the muscles most frequently paralyzed and is then the greatest hindrance to walking, because of flexion deformity of the knee. This should be prevented by a leather knee-cap attached to the upright of the brace.

In *gastrocnemius paralysis,* or even slight weakness of that muscle, the heels should be raised to prevent strain and stretching of the muscle by the superimposed body weight in walking. An elevation of the heel of a half to three-quarters of an inch in young children, and 1 to 1½ inches in older children, is necessary, while "bare foot" must be interdicted, even in undressing, and the use of sneakers and other heelless shoes absolutely forbidden, to avoid not only stretching of the gastrocnemius, but the production of permanent talipes calcaneus.

Objections to the use of apparatus are the extra weight and the muscular constriction caused by bands, lacings, etc., which hamper the already weakened muscles, but these objections are outweighed by the advantages gained. However, apparatus should not be worn except when actually required for walking, or to prevent deformity, and should be removed as often as possible.

The sense of equilibrium is often greatly impaired or lost by prolonged recumbency, and it is imperative to restore it before walking can be successfully accomplished. Loss of this sense must be reckoned with as a factor independent of the paralysis.

Patients with severe paralysis of the back, abdomen, and gluteal muscles require the support of a leather jacket with straps from the tops of the leg splints to the back of the jacket to act as substitutes for the gluteals and prevent flexion at the hips.

Fortunately the number of cases in which the loss of power consists only of muscular weakness, rather than of complete paralysis, comprise the vast majority of victims of the disease.

The active therapeutic measures of the convalescent stage aim at prevention of permanent deformity, and the restoration of nerve and muscle power. Massage, stretching of contracting muscles, and muscle training, are standbys in the therapeutics of this stage.

The *chronic stage* is marked by the cessation of spontaneous improvement. The lesions are stationary, and deformities and paralyses thoroughly established. When this stage has been reached, and the surgeon is truly convinced that a further return of muscle power is not possible, every case should be analyzed as to whether braces can be entirely eliminated, or can be diminished in their extent by some one of the operations above classified. This necessitates a very careful survey of the patient's musculature controlling each joint segment of the extremity, and consideration of the various operations which may be selected or designated to meet the particular conditions of the individual case. Meanwhile the full therapeutics of the convalescent stage are continued. It is at this chronic stage—about two years after onset—that the orthopedic surgeon many times sees these unfortunate patients for the first time.

The *examination* of such patients is important. First of all, the fear which so many children have of the doctor and the strange environment of his office, as well as their fear of pain during examination must be overcome. The surgeon must gain the confidence of his little patient, or the results of the examination will be valueless. In examining muscles, I have found it very helpful to designate their power by a scale of 0 to 4—4 indicating normal strength; 1, ¼ normal strength; and 0, nil, or complete paralysis. Taking the muscles of the foot for an example, we test the strength in flexion, extension, abduction, and adduction. If the plantar flexion is only one half normal, and the surgeon is confident that the child is applying all the force he can to that particular motion, he rates it as 2. The surgeon must make his own estimate, but comparison with normal muscles and normal joints on the opposite side aids materially in determining what constitutes "normal" strength for the individual in question. I repeat: examination should be delayed until the surgeon has the complete confidence of the child, in order that the muscle power may be estimated with accuracy.

I should like to speak here of the importance of muscles to joints—the whole usefulness of a joint depends on its proper control by the muscles attached. Further, it should be remembered that ligaments and capsules are weak and easily damaged in childhood. This is an important factor in treatment, for if these are properly supported until maturity, the joint will then stand a great deal of strain and abuse.

It will be evident from the foregoing discussion that *preventive treatment* is undertaken chiefly during the acute and convalescent stages of the disease. When the chronic stage is reached, we become concerned with *definitive* or *corrective treatment.*

Aside from the paralysis and the possibility of its surgical relief, the most important sequelae of the disease from the standpoint of the orthopedic surgeon are the deformities and contractures, and instability.

The question of the etiology of paralytic contractures has given rise to a multitude of theories and provoked keen controversy. In general, a contracture is due, not as is so often erroneously believed, to shortening of the paralyzed, but to overactivity of the healthy muscle group antagonistic in action to the paralyzed muscle group. "The normal position of a joint in the living body is determined and maintained by the equilibrium existing between the various muscles surrounding the joint—brought about by the elastic tension of the muscles and tendons—also by muscle tone" (Vulpius). Or, in other words, structural shortening occurs because, in the growing period of the child's life, the tonicity and elasticity of normally innervated muscles cause them to remain permanently in a shortened state in the absence (paralysis) of that stress normally brought to bear upon them by antagonistic normal muscle. This structural shortening is secondary to the contraction following unopposed muscle-pull. It should be noted that underlying all is the physiological property of soft tissue always to "take up slack" during the growing period.

Total paralysis of a limb is followed by relaxation of the joint capsule and a flail-like condition of the joints of the limb. If malposition of the limb is maintained for any length of time, shortening occurs in those enervated muscles whose points of attachment have been approximated, and deformity of the limb accompanies these changes. The more extensive the paralysis the more severe the capsular relaxation, so that in children subluxation or even complete dislocation may occur.

Hypertrophy of the surviving muscles of a paralyzed limb almost universally occurs, and is a functional compensatory hypertrophy, *e.g.*, of the extensor longus hallucis for the paralyzed tibialis anticus; of the sartorius for the paralyzed quadriceps extensor femoris. Furthermore, compensatory hypertrophy occurs in the sound limb in unilateral paralysis, and the muscles of the arms are similarly affected in cases of paraplegia in which the arms are used as an aid in locomotion.

Prevention of Permanent Deformity

Permanent deformity is nearly always preventable, and its existence is usually an indication of neglect or ill-advised treatment on the part of those having had charge of the patient, particularly in the case of deformities of the feet. Deformity resulting from paralysis of the spinal and shoulder muscles is, of course, a different matter, and permanent deformity may be unavoidable in such instances.

There are three stages in the development of deformity: (1) sustained malposition, which is remediable without the use of force; (2) lengthening of the soft parts on the stretched side of the joint, with shortening on the other side. In exceptional cases, the joint remains flail-like; (3) permanent structural bony and ligamentous deformity, due to adaptation of the growing bone to the vicious position. Gravity or weight-bearing may produce further deformity in a flaccid extremity. Unopposed muscle pull is also a factor.

Operative Treatment

Operative treatment is designed to accomplish three purposes: (1) correction of fixed deformity, (2) stabilization, and (3) improvement of muscle function. Sometimes one operation will serve all purposes, but occasionally deformity is so serious that its entire correction must first be accomplished, and improvement of muscle function by transplantation deferred until a later operation. A transplanted muscle should never be required to correct or maintain correction of a deformity. In fact, the anatomical architectural plans of the surgeon should be such, if possible, that the transferred muscle will function under more favorable mechanical conditions even than the muscle for which it was transplanted. This may involve stabilizing joints or changing relationship of bony skeleton by arthrodesis, silk or fascial ligaments, bone transplantation, etc.

The scope of this paper will not begin to allow detailed mention of all operations which can be approved of in the proper management of infantile paralysis. Therefore only the most striking, most recent, and those most far-reaching in their influence upon the return of function, or presenting peculiar technical difficulties will be discussed.

Preparation of the Field of Operation

The patient should be admitted to the hospital at least 24 hours before the operation. Immediately upon admission a generous field of operation is shaved, and cleansed with benzine. Then a generous coat of 3½ per cent. tincture of iodine is applied, over which a sterile dressing is placed. Just before operation this is removed, and a second coat of 3½ per cent. tincture of iodine is applied. For children under two years of age, the tincture of iodine is diluted with an equal amount of alcohol, otherwise the preparation is the same.

After the patient is under anaesthesia, a tourniquet is applied if necessary, and a generous skin incision and approach to the field of operation made. Irritation of muscles or tendons by prolonged exposure to air is avoided by keeping them constantly moistened with saline solution.

Operations

The following few operations, one for each joint segment, are chosen mainly to illustrate fundamentals, and no attempt has been made to cover all approved operative procedures for infantile paralysis, as time will not permit.

Operations on the Foot

Paralytic talipes valgus. Transplantation of peroneus longus and maintenance of correction of deformity by arthrodesis of the *astragalo-scaphoid joint.* One of the most troublesome cases from paralysis of one muscle is that of the anterior tibial developing into an extreme talipes valgus deformity. This is a most disabling one, owing to the weakness and distressing symptoms which follow in the foot.

Fortunately there is no weakness or distortion produced by infantile paralysis that is more satisfactorily relieved by surgical measures than this. And further there is nothing in the whole realm of orthopedic surgery which illustrates in a more pronounced way the necessity of devising and modifying operations to meet fully the mechanical defects present in the individual case.

Reasoning *a priori,* since the anterior tibial muscle is paralyzed or weakened, it might seem sufficient to the uninitiated merely to substitute the perineus longus, or the perineus longus and brevis, for the paralyzed anterior tibial muscle. But this is not the case, in that the very distortion following the weight bearing use of the foot with the tibialis anticus paralyzed is such that, when muscles are transplanted to take the place of the paralyzed one, they may tend to pull the foot into a more pronounced valgus rather than to correct the deformity. In other words, the distortion of the foot influences the direction of the pull to such a degree that, following the transplantation, it comes on the outside of the mechanical center of the midtarsal joints, rather than on the inside. It thus devolves upon the surgeon not only to correct, but to provide for the maintenance of the correction of the bony deformity at the same time that the muscle is transplanted. This can be done by the arthrodesis of the astragalo-scaphoid joint with the foot over corrected of its valgus and abduction. You will recall that the dorsal and plantar flexion of the foot and ankle comes almost wholly at the astragalo-tibial joint, and that here is very little lateral motion at this joint. On the other hand, the lateral motion of the midtarsal region of the foot comes almost wholly at the astragalo-scaphoid joint, and it is at the expense of this joint that the valgus deformity has occurred. Therefore, with the astragalo-tibial joint stable as to lateral motion, the arthrodesis of the astrogalo-scaphoid joint holds the forefoot stably corrected in the adductor position with the arch also corrected. Because of the already existing laxity of this joint and its increase by the removal of the articulating cartilage from both bones at operation, it is wise in many instances to peg the two bones together with a bone graft, according to a method recommended by Ogilvy.

Mayer and Biesalski have made a worth-while contribution to orthopedic surgery by utilizing the tendon sheath of the paralyzed muscle as a physiological path for the transplanted tendon or tendons. Thus, in case of paralysis of the tibialis anticus muscle, the perineus longus tendon is drawn to its new point of insertion through the sheath of the paralyzed tendon. Their experiments prove that a tendon transplanted by this new technic glides in its new bed with the same freedom as a tendon normally does. In other words, post-operative adhesions are entirely avoided by this new procedure. In all other instances, the subcutaneous tissues should be sufficiently tunneled to receive the transplanted muscle readily, and in a perfectly straight line.

Method of Inserting a Tendon

It is always preferable to transplant bone in the tendon end, and inlay this bone under trap doors of the periosteum and bone. If it is impossible to secure bone in the end of the transplanted tendon, the tendon end should be, whenever possible, anchored beneath bone. The transplantation of a tendon into a slit in another tendon is permissible, but not advisable, and should be avoided when possible. Bone tissue is specialized to withstand stress, and therefore when it is used to anchor tendons it proliferates under the influence of stress, precisely as it does when bony elements are actually coapted in a fracture or after a bone graft operation.

The tendon is anchored with No. 1 chromic catgut, or fine Kangaroo tendon. In some instances the transferred tendon may be sutured to the tendon it is functionally to replace, or some other tendon, and not seriously change its line of pull. These sutures may be absorbable and temporarily withstand all stress which might dislodge the tendon end from its implantation. Such is the case in the transplantation of the perineus longus or extensor proprius hallucis; the transplanted tendon is sutured firmly to the side of the anterior tibial tendon.

The fascia and soft parts are closed with O Chromic catgut continuous suture, and the skin is approximated by O catgut in continuous suture. *The line of suture* is then very carefully puddled with $3\frac{1}{2}$ per cent. tincture of iodine until every suture hole and the line of incision is thoroughly impregnated. From a long study of wounds incased in plaster of Paris casts for many weeks immediately following operation, the speaker is thoroughly convinced that there is danger from latent bacteria in the deep layers of the skin, and therefore he has inaugurated this so-called puddling of the suture holes and the edge of the skin, so that a film of tincture of iodine will remain upon the skin edges as well as in the suture holes while the dressing is applied, prior to the application of the plaster of Paris splint. This technic has been employed upwards of ten years with the greatest satisfaction, in all skin wounds associated with bone graft operations, tendon transplantations, and wherever long continued plaster of Paris dressings are necessary.

The plaster splint is taken off 3 to 4 weeks after the tendon transplantation operation. Its removal is immediately followed by massage, muscle training, and temporary braceage. The latter is almost always necessary, and should be very much emphasized, as a recently transplanted tendon is very likely to become over-fatigued if it is required to function in controlling a joint as well as in bearing weight. This is especially true in case of the foot. Of course it should be realized that in certain cases it may be necessary to apply some permanent bracage; in any event the amount should be much diminished as a result of the operative procedure.

Surgery of the infantile foot cannot be passed over without mention of the epoch making work of Whitman and Hoke.

Operations on the Knee

In the event of the complete paralysis or near paralysis of the quadriceps group, with the hamstring tendons intact, transplantation of the biceps femoris muscle affords very favorable results: 1—because the knee joint is a hinge joint, having motion in one plane, and 2—because the origin, insertion, and length of the biceps femoris muscle are favorable to transplantation into the upper outer corner of the patella.

The fundamental considerations in all tendon and muscle transplantations is especially emphasized in this instance, in that the muscle, without traumatizing its surface, be carefully freed by sharp dissection sufficiently far up, so that when inserted into the patella, it will pull in the straightest line possible.

The transference of this muscle also illustrates the cerebral re-education and control of a muscle to function in an entirely different way. Instead of a pure flexor, it becomes a pure extensor of the knee joint. This fact was a mooted one with the profession for a number of years, but has now become most thoroughly established by extensive repetition of the tendon transplantation by a very large number of orthopedic surgeons. One point in technic is important—the tension upon the transplanted tendon and muscle should be zero when the origin and insertion of the muscle are separated.

Operations Upon the Hip

Paralytic dislocation of the hip. For this most unfortunate condition an open operation is done which illustrates the great advantage of the plastic bone and joint technic. The hip is first reduced—this is easily accomplished. The acetabulum, the depth of which has been diminished by the wearing away of its rim as a result of friction from the constant slipping in and out of the head of the femur, is deepened artificially, as follows: The rim of the acetabulum is severed just outside and around attachment of capsule throughout its whole upper half circumference, then displaced outward, and a graft taken from just below the anterior superior spine of the ilium, is placed behind it. The capsule is then reefed with silk and medium Kangaroo sutures. This procedure deepens the acetabulum to beyond its normal depth. See Figures 1 and 2.

The Smith-Peterson approach to the hip is used.

A free exposure of the superior, anterior, and posterior portions of the capsule of the joint is given, together with its attachment to the acetabular rim; the posterior portion of the capsule is seen and felt to be lax, if the head is in the acetabulum, and if the head of the femur is disarticulated, it distends the capsule by pressure from beneath, and further displacement of the head is resisted. Upon manipulation of the femur, the head is readily felt as a rounded hard surface, slipping about beneath the capsule.

The amount of deficiency of the acetabular rim can be very easily determined at this stage by direct parpation, and manipulation of the head. Above the capsular attachment of the acetabular rim, the bone surface is cleared of soft tissue, and with a narrow thin osteotome the bone is incised just outside of the insertion of the capsule in a semicircular line over the posterior-superior-anterior aspect of joint. This curved acetabular bone segment is then pried downward and outward with the osteotome to deepen the acetabulum. The prying downward and outward of this curved superior bony rim segment produces still more laxity and wrinkling of the attached portion of the capsular ligament. The slack is taken up by reefing this portion of the capsule by a row of mattress sutures of kangaroo tendon placed obliquely to the long axis of the neck of the femur. The stitches are so placed as to make the reef of the capsule lie equidistant from the two ends of the capsular bone insertions. This takes up the slack of the capsule, and at the same time helps to hold the new formed acetabular rim in position.

After the rim of the acetabulum has been depressed, one or two small wedge-shaped portions of the upper surface of the gap are removed with a sharp osteotome, and into these are inserted the bevelled ends of short bone grafts. The other ends of these grafts rest on the depressed portion of the acetabular rim, thus producing permanent overhanging of the latter. When such grafts have been inserted, the more pressure is exerted on the rim of the acetabulum from muscle spasm or weight-bearing, the more firmly are the grafts and the new rim of the acetabulum held in place.

Arthrodesis of the hip. In the event of flail joints or complete paralysis, two joints are most favorable to arthrodesis—the hip and the shoulder. In both joints, bone grafts are very advantageous in aiding to secure immediate arthrodesis. The type of technic is extremely essential in obtaining the desired results. Every surgeon must realize that the operation for arthrodesis, even in non-pathological joints, must be performed with meticulous care, both as to design and execution of the technic.

The speaker was the first to design an arthrodesis operation for the hip, and published this in the J. A. M. A. in June, 1908. This consisted of the careful morticing of the head of the femur into the acetabulum. It was found, however, after the extensive use of this operation, that there were about 10 per cent. delayed unions, and about 5 per cent. non-unions. Therefore the operation was modified by sliding a broad graft from the outer table of the ilium down in contact with the overlying outer surface of the neck of the femur, which was split to receive the lower end of the graft as an inlay. This graft in the adult is used for all arthrodesis operations of the hip joint, and is approximately 1½ inches wide and 2½ inches long. If this technic is properly followed, a bony ankylosis will be secured in at least 98 per cent. of cases.

A prominent orthopedic surgeon has recently stated that he personally is unable to get more than 50 per cent. of ankylosis from arthrodesis without a bone graft. This merely emphasizes the necessity for unfailing attention to design and technique in such operations—a point which I have already stressed. We must remember that we are working counter to Nature's powerful efforts to perpetuate or restore the natural function of a joint—*motion*.

In the case of a flail joint at the hip, an arthrodesis furnishes a very serviceable limb, and cannot be too highly praised. There is considerable motion of the pelvis in relation to the trunk, controlled by strong muscles, therefore a fusion at the hip with the femur in proper relation to the pelvis brings about not only very satisfactory motion by virtue of compensatory motion at the lumbar spine but may bring about as much as two inches of practical lengthening in a shorter limb from delayed growth.

Operations on the Shoulder

At the shoulder, the same type of operation, with careful attention to the posture, gives even more brilliant results than at the hip, in that by arthrodesing the shoulder joint with the humerus anterior elevated and the hand in front of the face, while the scapula is flat against the thoracic wall, a very potent compensatory function is secured by virtue of the extensive range of motion of the scapula upon the thorax. If the scapula-thoracic muscles are intact, the function following such an operation is very surprising to patient and family, providing the muscles controlling the elbow and hand are also intact. For the helpless flail extremity, hanging limp from the shoulder, is transformed into one that is very satisfactorily controlled by the powerful scapulo-thoracic muscles.

The *technic* of arthrodesis in this joint I believe to be even more important than in the hip joint. "Beginning just internal to the acromioclavicular joint, a vertical incision is made downward to the outer side of the pectorodeltoid groove. The capsule is incised along the bicipital groove, and the synovia excised as thoroughly as possible, and any remaining is curetted away. Dislocate the head from the glenoid by sharp external rotation of the humerus. All cartilage is removed from the head and glenoid by osteotome or gouge, and from the approximating surface of the acromion process. While the scapula is held in good position by an assistant, return the head to the glenoid cavity and in close contact with the acromion process. With the arm held in slight internal rotation, elevated anteriorly at right angles to the body, and slight flexion at the shoulder (in such a position that by flexing the forearm the patient can touch mouth, head and neck), a bone graft peg is driven into the head of the humerus, through the acromion process. This latter procedure retains the position, increases fixation, and hastens bony union. The capsule is reefed to take up the slack and improve immediate immobilization. The arm and shoulder are fixed in the desired position in plaster of Paris, which immobilization is maintained for at least ten weeks."

This technic was first described by the speaker in a monograph entitled "Bone Graft Surgery," in 1917.

In controlling the patient during this operation upon the shoulder and also the arthrodesis upon the hip, it is almost imperative that the surgeon have the benefit of the Albee fracture orthopedic operating table, in order to control the posture of the extremity and the trunk during the operation, and during the post-operative immobilization by plaster of Paris splintage. (The Albee table is specified because there is no other which allows the upper extremity to be held in such postures during and after operation.)

Operations upon the Spine

I believe there is no more unfortunate deformity following infantile paralysis than the extreme case of paralytic scoliosis, and no condition is more unfavorable to treatment by conservative braceage. The spine takes the letter S curve. Both the thorax and the abdominal viscera are compressed, and discomfort and pain are caused in the more severe cases by the impingement of the lower ribs, as they telescope inside the pelvis.

In all cases of scoliosis we find primary and compensatory curves. The correction of the primary curve has a very material and direct corrective influence upon its compensatory curves. Therefore, in the case of paralytic scoliosis, correction of distortion and ankylosis by graft or fusion of the vertebrae, which make up most or all of the primary curve, has a very potent influence in diminishing the compensatory curves.

Here again plastic surgery has enabled the surgeon to do what was hitherto impossible for these most unfortunate cases. The bone graft is put in in a manner slightly different from that used in the speaker's operation for cases of anterior-posterior kyphoses, such as those observed in Pott's disease. In cases of paralytic scoliosis, the same mechanical principle is applied, but the graft is so placed that the deforming influence which acts laterally comes upon the graft edgewise. In other words, speaking figuratively, the graft is inserted into the spinous processes flatwise.

The following case is most illustrative of what can be done for these unfortunates by means of plastic bone surgery.

The patient, a man aged 20, as a result of infantile paralysis had a marked scoliosis of the type just described, with telescoping of the ribs, and also complete paralysis of the right quadriceps group of the right leg. It was thought that operative intervention had a much better chance of success by transplanting the right biceps forward for the quadriceps group, and therefore he was admitted to the Post Graduate Hospital, and the operation carried out as we have already described under transplantation operations.

A year later the patient returned to me, and was so much pleased with the improved function in his right leg following the operation, that he begged to have his spine operated upon. Therefore he was again admitted to Post Graduate Hospital, and was placed in the dorsal position upon a gas-pipe frame especially designed for him, and lateral corrective tension applied constantly for a period of two weeks. This constant stretching straightened the spine very materially, and the author's regular operation for Pott's disease was then done, with the variation in the placement of the graft already referred to. In other words, the spinous processes of the lower dorsal and lumbar vertebrae were split, and a graft inserted flatwise into these processes, using the graft as a lever to still further increase the correction of the scoliotic deformity. Fig. 3.

It was then found that, because of the extreme amount of lateral deviation at the lumbosacral junction, the floating ribs were still riding at about the level of the iliac crest; and fearful that relief from the pain of the telescoping of the ribs would not be complete, it was decided to put in a graft as a prop between the rim of the pelvis and the anterior end of the 10th rib.

A longitudinal incision through the skin and subcutaneous tissue was made from about 1½ inches back of the anterior end of the 10th rib, directly downward to the crest of the ilium. The ribs were then by strenuous lateral tension forced above the crest of the ilium as far as possible. A measure was then taken of the distance between the rim of the pelvis and the rib; this was found to be about 6 inches. The rib was mortised as well as the ilium, to receive the tibial graft properly. The wound was packed with hot saline, and the anterior internal surface of the right tibia was exposed for a distance of about 8 inches. A graft 6 inches long and ½ inch wide was removed by means of the twin motor saw, and the central portion of the anterior internal surface, including the complete thickness of the cortex of the bone with its periosteum, and as much marrow as would cling thereto. The ends of the graft were then notched by removing a triangular piece of bone from each end. The pack was removed from the olio-thoracic wound, and by means of elevating the ribs as far as possible from the crest of the ilium, the notched ends of the graft were inserted into the mortices already prepared for it. These ends were firmly held in place by sutures of medium Kangaroo tendon placed in the bones and the periosseous structures at either end. Both wounds were closed in the usual way.

With the patient still in the ventral position on the Albee Fracture-Orthopedic operating table, a plaster of Paris jacket was applied from the base of the skull and well under the arms to below the crest of the ilium. This was specially molded during the hardening period, so that it acted as an overcorrecting influence on the lateral deformity of the trunk.

The patient made an uneventful recovery, and has been one of the most successful cases I have ever had the privilege to operate upon. This operation was done in January, 1923, so that I can speak with confidence of the results.

I have purposely said very little about muscle training, for this is a subject meriting a paper by itself. It is one of the great assets in the armamentarium of the orthopedic surgeon, both preoperatively and postoperatively, as well as in cases in which operation is not indicated. Muscles that have been weakened or have been temporarily paralyzed, with subsequent return of power are in many instances not properly controlled, and the child is unable to contract them fully at will. This emphasizes the necessity for muscle training in all cases. There is one striking difference between pre- and post-operative muscle training: the former develops individual muscle power; the latter educates the brain to make the transplanted muscle function in an entirely different way.

I should like to leave you with a picture of nearly 600 muscles with all types and variations of paralysis and weakening, reflecting a corresponding variety of distortions on the skeleton; for extremity and trunk postures are wholly dependent upon muscle balance. It is evident, with such a picture in mind, that the braceage, muscle training, and operative management of infantile pralaysis cannot be stereotyped. No two cases are alike, and the orthopedic surgeon must not only be a good technician, but a mechanical genius, ready at a moment to devise mechanical apparatus or reconstruction operations as called for by the conditions in the individual case.